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Best Available Technology (economically achievable) Guidance Document for the Hanford Site

Waste Management
Systems Engineering

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Prepared for the U.S. Department of Energy
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EXECUTIVE SUMMARY

This document provides Westinghouse Hanford Company (Westinghouse Hanford) and the U.S. Department of Energy (DOE) with a step-by-step procedure for the identification and documention of the Best Available Technology (BAT) economically achievable for treating liquid effluents on the Hanford Site. The BAT determination is a key element in the DOE strategy to eliminate use of the soil column for contaminated effluents disposal. Following application of BAT, a liquid effluent is considered suitable for discharge to the environment, including the soil column.

Liquid effluents on the Hanford Site are currently disposed of in accordance with DOE orders that require protection of public health and safety, and to the extent possible, minimize adverse impacts on the environment. The determination of BAT on a liquid effluent will only occur after the effluent meets all applicable release limits. As a result, the application of BAT may involve an additional level of control, as well as contribute to the overall Hanford Site as low as reasonably achievable (ALARA) program.

The BAT determination procedure presented in this document involves the following five steps:

- Assemble all relevant liquid effluent data
- Determine BAT by the effluent guidelines method
- In the absence of relevant effluent guidelines, determine BAT by the technology transfer method
- In the absence of applicable technology transfer, determine BAT by the treatability studies method
- If the treatability studies method is not adequate to establish BAT, use the generic treatment system method to identify a range of potentially applicable and acceptable treatment systems.

As part of the technology transfer, treatability studies, and generic systems methods, an analysis of the economic achievability of the control technology will be made.

The first step in applying the BAT guidance procedure is to assemble all liquid effluent quality and quantity data to establish the treatment requirements associated with a particular effluent stream. The second step involves determining the BAT by the effluent guidelines method. In this method, Federal and State effluent guidelines are used to establish the BAT. Any combination of measures that would meet these limits is considered BAT, and is assumed to be cost effective. If no such limit exists, BAT is determined on a case-by-case basis, using Best Professional Judgement (BPJ). The remaining steps in this BAT determination procedure are based on U.S. Environmental Protection Agency (EPA) BPJ criteria.

If effluent guidelines are not adequate to determine the BAT, then the third step will attempt to determine BAT by the technology transfer method. In this approach, information on full-scale BAT treatment systems operating on similar effluent streams would be used to establish BAT. Because very few BAT treatment systems exist for radioactive effluents similar to those at the Hanford Site, the technology transfer method will be used after BAT has been established on several Hanford Site effluent streams.

The fourth step involves determining the BAT by the treatability studies method. This approach is similar to the technology transfer method, with the exception that information from treatability studies is used to broaden the range of the technology transfer. This method requires more detailed information for both the comparison of the treatment system influent characteristics and projected removal performance, based on reasonable engineering assumptions and bench-scale tests.

The fifth step involves determining the BAT by the generic treatment systems method. This method takes information from treatment systems used within and outside the nuclear industry, and develops an array of potential BAT treatment systems; it includes treatment system identification, preliminary screening, a zero discharge assessment, decision analysis, and an economic achievability examination. This approach is envisioned to be applicable to all Hanford Site effluent stream discharges.

Two methods are presented for determining economic achievability. The first method is patterned after tests the EPA applies to commercial enterprises and compares plant operating costs to pollution control costs. This test is used to determine if the treatment costs are reasonable in comparison to the economic scale of the enterprise. The second method is a cost-effectiveness test and is based on the fundamental idea that cost of controls should be reasonably related to benefits of controls.

This BAT procedure addresses pollutants that have not been regulated under traditional State or Federal water-pollution control programs. As a result, applicable regulatory programs impose few constraints on the selection of treatment alternatives. While the concepts that underlie these regulatory programs are highly appropriate for determining the BAT for Hanford Site effluent streams, the experience base for implementing these concepts is very limited. As a result, a significant amount of flexibility exists in defining BAT controls. In many cases, it may not be possible to identify a unique control alternative that is BAT. In these cases, the DOE and Westinghouse Hanford will have to select technologies from a set of alternatives, considering cost and control effectiveness.

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1.0 INTRODUCTION

The U.S. Department of Energy (DOE) has established requirements for disposal of liquid effluents on the Hanford Site and requires compliance with applicable U.S. Environmental Protection Agency (EPA) and Washington State regulations. Although current liquid effluent disposal practices at the Hanford Site are conducted according to DOE requirements, continued use of the soil column for disposal of liquid effluents and protection of surface and groundwaters is a concern to the DOE.

It is the DOE policy to replace the use of soil column disposal practice for contaminated liquid effluents with alternative waste treatment and disposal methods (DOE 1984). In accordance with this policy, the DOE-Richland Operations Office (DOE-RL) was directed by the U.S. Congress to provide a plan and schedule to discontinue disposal of contaminated liquid effluents into the soil at the Hanford Site (DOE-RL 1987).

In the DOE strategy to replace the use of the soil column for the disposal of contaminated effluents, a key element is the determination of Best Available Technology (BAT) economically achievable. This document provides Westinghouse Hanford Company (Westinghouse Hanford) and the DOE-RL with a step-by-step procedure for the selection and the documentation of BAT for the treatment of contaminated liquid effluents. Following the application of BAT, a liquid effluent is considered to be suitable for discharge to the environment, including the soil column.

1.1 REGULATORY CONCEPTS

This section provides a brief overview of regulatory concepts applicable to the identification of BAT controls for Hanford Site liquid effluents, which are discharged currently to the soil column. These concepts are consistent with the goals of the Clean Water Act (CWA) (EPA 1987b) and the policy of the Washington Water Pollution Control Act (WWPCA) (Ecology 1983c).

Under the CWA, the U.S. Congress established the National Pollutant Discharge Elimination System (NPDES) Program. This program requires that BAT be applied to control toxic pollutants in effluents prior to discharge to navigable waters. The BAT is an aggressive level of treatment, but is still limited by the requirement of economic achievability. The CWA and NPDES Program do not regulate nor authorize regulation of the discharge of source, special nuclear, or by-product materials covered by the Atomic Energy Act (AEA) (AEA 1954); nor do they govern discharges other than discharges to navigable waters.

The NPDES Program has been implemented by the EPA and in states with approved NPDES Programs for major industrial categories through rulemakings that have set binding liquid effluent limits for discharges to navigable waters. These technology-based limits are based on detailed studies of industrial effluents and control technologies, to determine applicable control approaches and achievable contaminant concentrations in liquid effluents. Presently, no Federal nor state industrial category liquid effluent limits exist that are applicable to the Hanford Site liquid effluents, which are discharged to the soil column.

Where Federal or state liquid effluent limits have not been established, a case-by-case assessment is used to determine, or to verify that the discharger has determined, the BAT economically achievable.

Washington State has implemented the NPDES Program through Washington State Administrative Code (WAC) 173-220 (Ecology 1974) and regulates certain other non-NPDES nonradioactive discharges under WAC 173-216 (Ecology 1983a). The WAC 173-216 regulations do not contain specific and precise standards capable of uniform application, and they have not been applied uniformly. The general goal of the regulations are to provide for the use of all known, available, reasonable controls, and protection of beneficial uses of groundwater. This guidance procedure considers BAT treatment to fulfill the substantive requirements of WAC 173-216.

1.2 BEST PROFESSIONAL JUDGEMENT

When there are no applicable liquid effluent limits for a particular effluent stream, BAT controls are determined on a case-by-case basis through the use of Best Professional Judgement (BPJ). Key factors that must be considered in exercising BPJ are delineated in the CWA and in recent EPA training manuals (EPA 1981a; 1981b; and 1986).

Established BPJ criteria and limits resemble a collection of basic statements, rather than a description of a step-by-step process to uniquely identify BAT. This is largely because defining BAT using BPJ is a matter of balancing competing considerations in different sets of circumstances. Regulatory criteria identify key considerations (including engineering opportunities, environmental objectives, and economic realities) and provide some guidance in striking a balance between these considerations. Other BPJ criteria and guidelines help ensure consistency in decision making across similar cases, and protect against making arbitrary decisions.

1.2.1 Best Professional Judgement Criteria

According to the EPA, BPJ is "the highest quality technical opinion developed by a permit writer after consideration of all reasonably available and pertinent data or information" (EPA 1986). It is implicit in the listing of the criteria that the BPJ process is a comparative process. An initial reference point for control technologies and performance is needed to apply most of these criteria. This reference point may be found in liquid effluent limits, practices at other sites, EPA treatability manuals, or in the results of treatability studies. With a reference point established, necessary adjustments in liquid effluent limits are determined, while considering the following factors:

- Equipment and facility age
- Treatment process used
- Engineering aspects of control techniques
- Process changes
- Nonwater quality environmental impacts
- Cost of achieving effluent reductions.

1.2.1.1 Equipment and Facility Age. Facility age affects the feasibility, costs, and reasonableness of inplant process modifications to reduce pollutant discharges. This is likely to be a limiting factor for process modifications and end-of-pipe treatment systems at the Hanford Site, where major facilities are nearing retirement age.

1.2.1.2 Treatment Process Used. The nature and capabilities of the liquid effluent treatment process(es) used at a facility must be considered in setting BAT treatment requirements. Typically,

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the effectiveness of a treatment technology will vary for different pollutants; these variations should be considered and reflected in BAT determinations.

1.2.1.3 Engineering Aspects of Control Techniques. The BAT performance criteria must be limited to treatment technologies or process modifications that are feasible from an engineering standpoint. At the Hanford Site, the volumes and radiation levels of some streams, and the age and layout of facilities, may result in significant engineering limitations on control techniques that might otherwise be feasible.

1.2.1.4 Process Changes. The feasibility of any process modifications that would reduce the quantity or toxicity of a discharge should be considered. Potential process changes include spill control, raw materials substitution, waste stream segregation, recycling, cascade water use, and zero discharge systems.

Complex inplant process modifications such as closed-loop systems will also greatly reduce discharges, and may be more cost effective than end-of-pipe treatment. Some process modifications used commonly for nonradioactive streams may not be feasible for Hanford Site streams, due to engineering or worker safety considerations, and existing facility designs.

1.2.1.5 Nonwater Quality Environmental Impacts. All nonwater quality environmental impacts associated with the potential treatment technology must be considered during the BPJ process. These nonwater quality impacts include air pollution, solid waste generation, radiation exposure, and energy requirements. The preferred treatment technologies must be consistent with other applicable regulations and must have the least severe nonwater quality environmental impacts.

1.2.1.6 Cost of Achieving Effluent Reductions. The economic feasibility of a technology or process modification proposed to meet BAT treatment requirements is typically considered during the BAT determination process. Economic achievability is not the only means through which cost considerations enter BAT determinations. The BAT must be available, and as a result, extremely costly technologies are unlikely to be developed and/or demonstrated sufficiently to meet the criterion of availability.

For Federal facilities such as the Hanford Site, there are no prescribed methods nor policies for defining economic achievability as a separate screening step in the selection of effluent controls. There are two methods presented in this procedure for determining economic achievability. These procedures are discussed in Section 8.0.

1.3 PERSPECTIVE OF THE BEST AVAILABLE TECHNOLOGY DETERMINATION PROCESS

The previously discussed concepts are considered appropriate to determine BAT for the treatment of radioactive and nonradioactive components of the liquid effluents on the Hanford Site. These control programs and their associated regulatory guidance leave a wide range for the exercise of engineering judgement in the determination of BAT and in the selection of technology-based release limits. This discretion is used commonly by regulatory agencies, to balance the cost of control measures against the benefits of the control.

Prior BAT decisions, under the CWA, normally provide a reference point to begin the BAT selection process. However, application of this approach to controlling radionuclide releases is a new action because source, special nuclear, and by-product radionuclides are not regulated by the CWA; therefore, no CWA experience is available for applying these principles to radioactively contaminated liquid effluents. Treatment measures used to control radiation risks at DOE facilities are selected outside the BAT context, and as a result, may not provide a basis for the selection of BAT or the determination of technology-based release limits.

Due to the role judgement plays in the BAT determination, it may not be possible to identify a unique control alternative that is BAT. In these cases, the DOE and Westinghouse Hanford will have to select the BAT from a set of alternatives. This selection process will have to balance the economics of the treatment alternatives and the need for additional controls to protect Hanford Site groundwater.

The guidance provided in this document will form the basis for making the BAT determination and provide the appropriate documentation to support the selection. This evaluation will only be applied to liquid effluents which meet all applicable release limits. It is also intended that the BAT evaluation will support and contribute to the overall Hanford Site ALARA program.

2.0 PROCEDURE FOR DETERMINING BEST AVAILABLE TECHNOLOGY

This section presents a general description of the BAT guidance procedure, which will be used to define BAT for the contaminated liquid effluent streams discharging to the soil column on the Hanford Site. This procedure is intended to form the basis for making the BAT determination and to provide the appropriate documentation to support the selection.

The decision tree for the BAT selection procedure is shown in Figure 1. The procedure involves a five-step approach to a BAT determination for a particular liquid effluent stream. The steps in this hierarchical approach are as follows:

- Assemble all relevant liquid effluent data
- Identify BAT by the effluent guidelines method
- In the absence of relevant effluent guidelines, determine BAT by the technology transfer method
- In the absence of technology transfer, determine BAT through the treatability studies method
- If treatability analysis is not adequate to establish BAT, use the generic treatment system method to identify a range of potentially applicable and acceptable treatment systems.

As part of each BAT determination step, an assessment is made of the economic achievability of the control technology.

Liquid effluents on the Hanford Site are discharged currently in accordance with DOE Orders that require protection of public health and safety, and are intended to control and (to the extent possible) minimize adverse impacts on the environment. As such, application of BAT for liquid effluents may result in an additional level of control as well as contribute to the overall as low as reasonably achievable (ALARA) program at the Hanford Site.

The BAT determination process begins with a review of relevant DOE, Nuclear Regulatory Commission (NRC), and EPA liquid effluent guidelines; and subsequent analysis of Washington State Law RCW 90.48 (Ecology 1983c) and regulations WAC 173-216, 173-218, and 173-220 (Ecology 1983a; Ecology 1983b; and EPA 1987b). These standards provide a general guidance regarding the regulatory meaning of BAT.

For most significant industrial categories, BAT has been defined by EPA through regulation under the NPDES Program. For Hanford Site liquid effluent streams, BAT would be any combination of measures that could meet applicable discharge limits. If no such limits exist for an individual source, BAT is determined on a case-by-case basis, using BPJ. Criteria to be used in this type of an evaluation have been discussed in Section 1.0, and form the basis for the remaining steps in the BAT selection procedure.

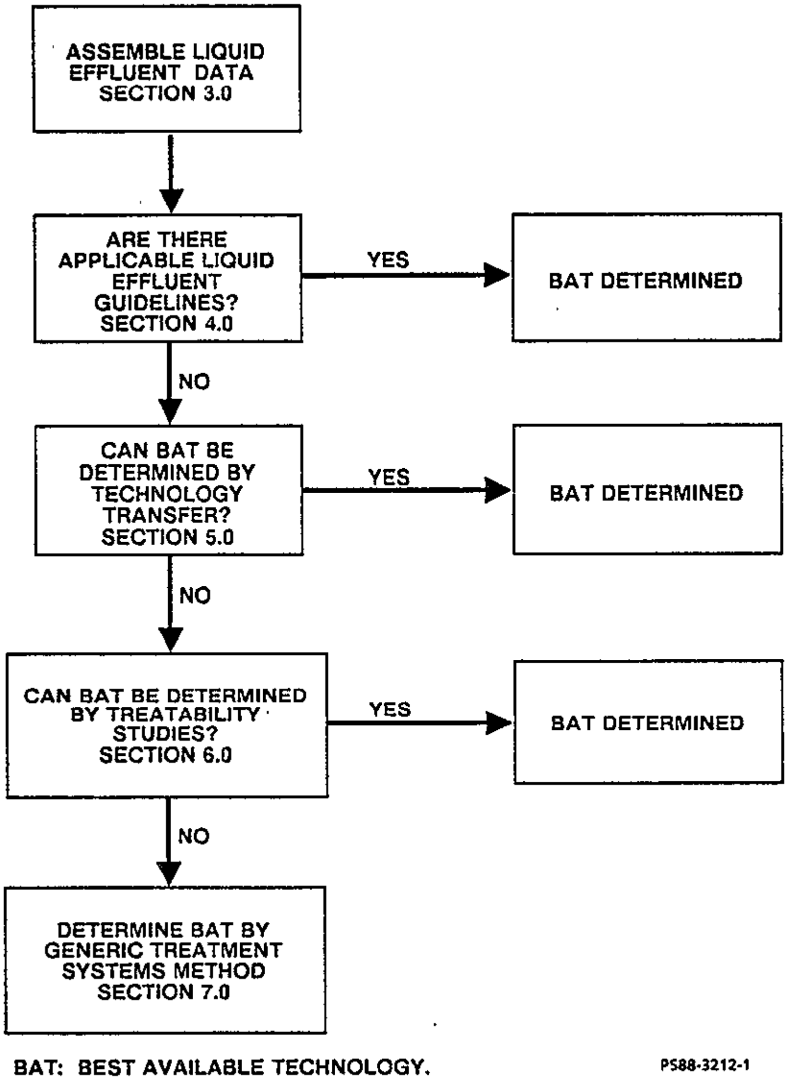

Figure 1. Best Available Technology Guidance Procedure.

If a BAT determination is not possible from the effluent guidelines method, then it may be possible to establish BAT by the technology transfer method. If full-scale BAT treatment systems exist, then a comparison of Hanford Site liquid effluents to these treatment systems could be made to establish BAT. Because few treatment systems exist on liquid effluent streams similar to those at the Hanford Site, the technology transfer method will be used most likely after BAT has been established for similar streams at the Hanford Site.

Determination of BAT by the treatability studies method is similar to the technology transfer method, except that information from the treatability studies method is used to broaden the range of the application of the technology transfer method. Again, full-scale BAT treatment system information and treatability studies information may be used, where available, for comparison to Hanford Site effluent streams to establish BAT. This method requires more detailed information for both the comparison of treatment system influent characteristics and projected removal performance, based on reasonable engineering assumptions.

A BAT determination by the generic treatment system method takes information from known treatment systems used within and outside the nuclear industry to develop an array of potential BAT treatment systems. This method includes treatment system identification, preliminary screening, zero discharge assessment, decision analysis, and an economic achievability examination. This method is envisioned to be applicable to all Hanford Site liquid effluent stream discharges to the soil column.

Commercial and industrial facilities are not required to implement controls unless they are economically achievable. However, established tests of economic achievability cannot be applied directly at the Hanford Site without modifications because the tests draw on economic indicators (e.g., revenues) that do not exist at the Hanford Site. Nevertheless, economic achievability is relevant, and can be an important limiting factor in control intensity where there are no technical limits on the removal of pollutants. There are two methods presented in Section 8.0, for the determination of economic achievability. The first method is patterned on a test the EPA applies to commercial enterprises and compares plant operating costs to pollution control costs. This test is used to determine if the costs are reasonable in comparison to the economic scale of the enterprise. The second method is a cost-effectiveness test and is based on the fundamental idea that the cost of controls should be related to the benefits of controls (see Section 8.0).

3.0 ASSEMBLE AND ASSESS LIQUID EFFLUENT DATA

The first step in applying the BAT guidance procedure is to identify and quantify the radioactive and nonradioactive contaminants in the liquid effluent. This information will be needed to establish treatment requirements and identify practical treatment technology.

The data should be adequate to determine the proportions of radiological pollutants in the form of suspended solids (solids with a particle size greater than 0.45 microns) and dissolved solids in each liquid effluent stream. This information is useful for evaluating and selecting suspended solids removal technologies such as filtration, sedimentation, and ultrafiltration. If most of the radionuclides are present in the suspended solids, BAT may be achieved without the removal of the dissolved solids. The amount of dissolved radiological pollutants is also important for the selection and evaluation of dissolved solids removal technologies. These technologies include ion exchange, reverse osmosis, distillation, evaporation, and precipitation.

The nonradiological pollutants can be either inorganic or organic substances that have been classified by the CWA as conventional, priority, or nonconventional pollutants as described in Standard Methods (AWWA 1980) and 40 CFR 136 (EPA 1987b). The nonradiological conventional pollutants include total organic carbon, pH, total suspended solids, and oil/grease. These pollutants are principally of environmental concern in aquatic environments, but can also affect operation of treatment systems. The priority pollutants are comprised of 129 toxic inorganic and organic substances established by EPA as described in Section 307 of the CWA and listed in 40 CFR 136 (EPA 1987b). The CWA requires treatment of all priority pollutants, using BAT, prior to discharge to surface waters. Nonconventional pollutants are typically all other pollutants of concern not identified as conventional nor priority pollutants (e.g., nitrates or radionuclides).

An example of the information needed for a BAT determination is shown in Table 1. Other information may be required if specific priority, nonconventional, and radiological pollutants of regulatory concern are contained in a particular liquid effluent stream.

The characterization of liquid effluent volume is as important as the radiological and nonradiological characterization of the liquid effluent quality because the size of the treatment system is flow dependent. The use of water recycle, reuse, cascading, or zero discharge can reduce significantly the volume of an effluent stream. Another important factor is flow equalization, which directly affects the operability and pollutant removal efficiency of the selected treatment system (EPA 1973; 1974a; and 1974b).

Source control and waste minimization efforts will influence the quantity of liquid effluents requiring treatment. For example, water reduction and segregation of contaminated streams can both increase and decrease the concentration of contaminants in the liquid effluents.

Both liquid effluent quality and quantity information is necessary to identify the type and size of each BAT treatment system. Without good liquid effluent stream data, only very generic treatment systems can be identified. Data requirements outlined in this chapter must be supplemented by treatability studies for these liquid effluent streams that are characterized poorly.

Table 1. Example of Water Quality Data Needs.

General criteria	Cations	Trace metals	Anions	Organics	Radionuclides
Flow[a] pH Total suspended solids Silt index[b] Total dissolved solids Alkalinity Temperature Oil/grease Total organic carbon Gross alpha Gross beta	Aluminum Sodium Silica Calcium Magnesium Potassium	Lead Calcium Chromium Barium Mercury Silver	Sulfate Chloride Nitrate Fluoride	Acid/Base/ Neutral extractable organics Volatile organics	Gamma spectrum Tritium ^{129}I ^{90}Sr ^{137}Cs ^{60}Co ^{106}Ru ^{99}Tc

[a]Minimum, daily average, maximum.

[b]Functional test that is often specified for membrane technologies.

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Options such as closed-loop and zero discharge systems require evaluations at the bench- and/or pilot-scale level (NALCO 1988; and EPRI 1985). This is particularly important for both a closed-loop steam condensate or cooling water system. These types of systems require a number of water quality variables to be monitored routinely to control potential scaling, corrosion, and biological growth. If these options are being evaluated, a very intensive liquid effluent characterization program will be required.

4.0 BEST AVAILABLE TECHNOLOGY DETERMINATION BY EFFLUENT GUIDELINES METHOD

Federal and state effluent guidelines developed under the NPDES Program, that are relevent or applicable may establish BAT. Other standards may also provide useful guidance on acceptable effluent quality, environmental exposure, or control intensity. Preliminary BAT determinations involving control measures that fall short of those standards should be carefully reviewed.

The effluent guidelines method to determining BAT is shown in Figure 2. A general discussion pertaining to liquid effluent guidelines is presented in Section 4.1. Radiation exposure limits are discussed in Section 4.2. Other potentially applicable water and liquid effluent regulations are discussed in Section 4.3.

4.1 LIQUID EFFLUENT GUIDELINES

Under the CWA, effluent limits have been established for 34 industrial source categories. These technology-based limits establish the BAT for these industrial source categories. There are no CWA industrial source effluent guidelines directly applicable to the liquid effluent discharges on the Hanford Site. However, some Hanford Site processes may correspond closely to subactivities regulated under existing industrial source effluent guidelines. Where matches of this kind can be made, the discharge limits set in the effluent guidelines are strong candidates for consideration in establishing BAT. For example, effluent guidelines for metal-cleaning wastes and cooling waters at steam electric power plants should be reviewed in developing BAT for any Hanford Site effluent stream affected by heat-exchanger cleaning or water recycling activities.

4.2 RADIATION EXPOSURE LIMITS

Radiation protection standards established by the DOE, EPA, and NRC for offsite or uncontrolled areas may be considered analogous to water quality standards within the NPDES Program. These standards set upper bounds on the acceptable consequences of a discharge, with these bounds expressed in terms of risk, rather than pollutant concentrations.

The DOE has established requirements for the disposal of liquid effluents on the Hanford Site. These requirements are contained in a set of orders that require protection of public health and safety and are intended to control, to the extent possible, minimal adverse impacts on the environment. Liquid disposal practices on the Hanford Site are conducted in accordance with these requirements. As such, the application of BAT on the liquid effluents may result in an additional level of control, as well as contribute to the overall ALARA program at the Hanford Site.

The EPA limits for total annual radiation doses to members of the public are 25 mrem/yr to the whole body, 75 mrem/yr to the thyroid, and 25 mrem/yr to any other organ (40 CFR 190 and 191 Subpart A) (EPA 1987b). The limits specified in 40 CFR 190, for commercial electric power generation, apply to the cumulative effects of all activities that are part of a nuclear fuel cycle. The limits specified in 40 CFR 191 are for activities related to the management and disposal of spent nuclear fuel, high-level, and transuranic radioactive wastes at any facility regulated by the NRC; or at DOE disposal sites for transuranic wastes, spent fuel, or high-level wastes. Similar limits may be included in future 40 CFR 193 (EPA 1987b) regulations.

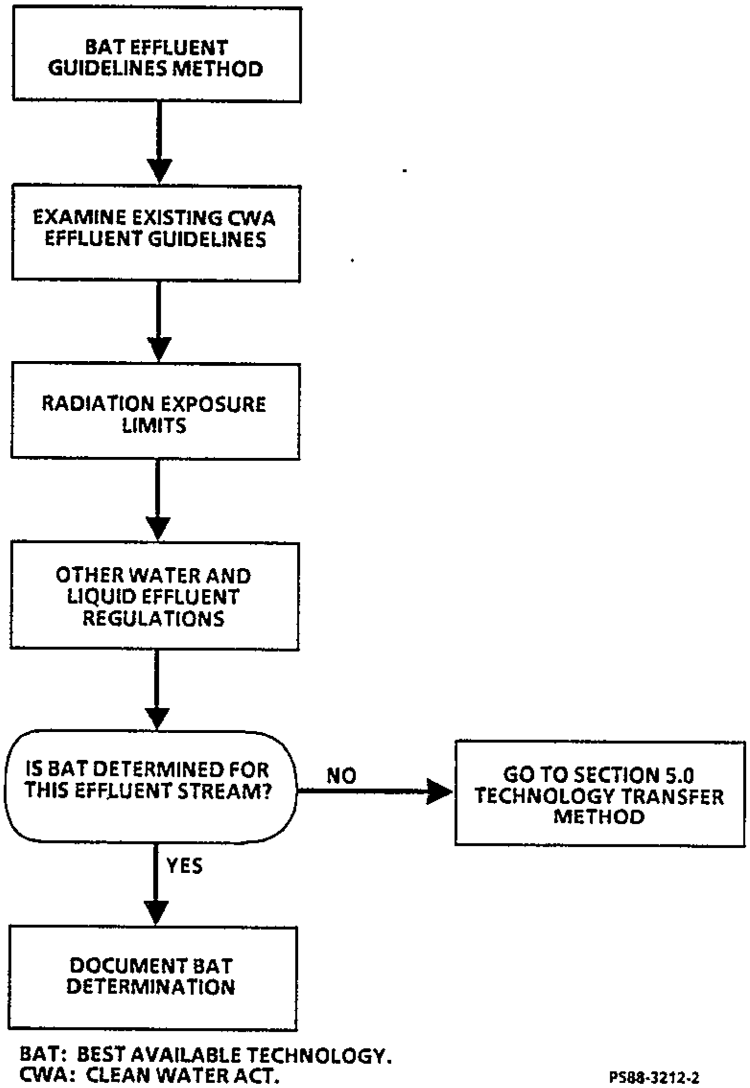


Figure 2. Effluent Guidelines Method to Best Available Technology.

The NRC regulation 10 CFR 50 (EPA 1987a) sets licensing standards for nuclear facilities, including some reactors operated to produce primarily uranium and plutonium, and some separation facilities. Although Hanford Site facilities are exempt from 10 CFR 50, these standards provide guidance on design objectives and limiting conditions for radiation releases.

Standards established for new commercial reactors under the AEA may be equal to or more stringent than standards that may be established using a BAT determination; 10 CFR 50 requires that these new facilities be designed and operated to comply with ALARA, as designated by 10 CFR 50, Appendix A numerical standards. Appendix A standards limit offsite doses from each reactor to not more than 3 mrem/yr to the whole body and 10 mrem/yr to any organ, and additionally require all controls that can reduce exposures within a 50-mi radius at a cost of $1,000/man rem or less, be used.

Appendix A of 10 CFR 50 further advises that the maximum dose in unrestricted areas due to all liquid effluents from all reactors at a site should not exceed 5 mrem/yr, and that radiation releases in liquid effluents from each reactor should not exceed 5 Ci/yr. The standards are set without regard to the types of water quality and use evaluations that are relevant under the CWA.

4.3 OTHER LIQUID EFFLUENT AND WATER QUALITY STANDARDS

Under the NPDES Program, sufficiency of BAT controls for discharges to surface water is tested by assessing the impacts of the discharge on water quality. This standard of reference is sufficiently important, that in practice, the somewhat theoretical BAT determination process is sometimes supplanted by an iterative process driven by actual water quality impacts. In this process, controls will be established, and water quality will be monitored; if targets are not met, further controls will be added until the targets are met.

At the Hanford Site, surface water quality is not a concern for most discharges, but surface and groundwater quality standards can provide guidance on whether the controls are sufficient. Drinking water standards are also relevant, but should be applied at the time and place of presumed drinking water use and should not be applied directly to effluent discharges to the soil column.

Washington State has established water quality standards for radiation (WAC 173-201), but these standards are not strictly numerical (Ecology 1973). As a guideline, radioactive materials are considered to be present in "deleterious concentrations" if they are greater than 1/100 of the Table II values in 10 CFR 20, Appendix B, are above the Safe Drinking Water Act maximum concentration limits (MCL), or are higher than the lowest practicable concentration obtainable. Based on WAC 173-201, concentrations in Class A (Excellent Quality) waters must be "below those of public health significance, or which may cause acute or chronic toxic conditions to the aquatic biota, or which may adversely affect any water use." The Hanford Site portion of the Columbia River is a Class A stream (WAC 173-201) (Ecology 1973). In Class B (Good Quality) and C (Fair Quality) waters, concentrations must be "below those which adversely affect public health during characteristic uses, or which may cause acute or chronic toxic conditions to the aquatic biota, or which may adversely affect characteristic water uses."

Drinking water standards for radionuclides have been established by the EPA. Gross alpha particle activity (excluding uranium) cannot exceed 15 picocuries per liter (pCi/L). Excluding dose from alpha particles, the dose that would be received from drinking 2 liters of water per day cannot exceed 4 mrem/yr. (Tritium is presumed to cause this dose at a concentration of 20,000 pCi/L, and strontium at a concentration of 8 pCi/L.) The EPA has proposed new drinking water concentrations for radionuclides based on a 10^{-6} risk level and exposures of 4 mrem/yr.

These drinking water limits must be met in community water systems, and in some situations, the EPA has proposed to use drinking water limits as applicable or relevant and appropriate requirements (ARAR) for Comprehensive Environmental Response Compensation and Liability Act (CERCLA) cleanups. Drinking water standards are also presumptive cleanup standards under the Resource Conservation and Recovery Act (RCRA). Under both RCRA and CERCLA, however, alternative cleanup limits may be established where these are protective of human health and the environment.

A reasonable application of drinking water standards at the Hanford Site is to require that they be met outside the future control zone (FCZ) (DOE 1987) after loss of institutional control, because this is where use as drinking water may occur. As part of the process of setting effluent standards to protect groundwater quality at the Hanford Site, consideration should be given to the uptake of radionuclides in the soil column.

Testing consistency with drinking water standards at the time and place of potential use of the Hanford Site aquifer is consistent with EPA actions to-date in setting groundwater quality standards related to radiation. Numerical standards can be found in 40 CFR 191 Subpart B (for radioactive waste disposal), and in 40 CFR 192.32 (for uranium by-product materials disposal) (EPA 1987b).

Levels of groundwater contamination where corrective action must be implemented at uranium by-product material sites are specified under 40 CFR 192.32 (EPA 1987b). The regulatory approach is based on RCRA, and control requirements are triggered when gross alpha particle activity (excluding radon and uranium) exceeds the drinking water standard of 15 pCi/L. Alternate concentration limits may be established where these are ALARA and where the basic standards will still be met at all points more than 500 meters from the disposal area.

5.0 BEST AVAILABLE TECHNOLOGY DETERMINATION BY TECHNOLOGY TRANSFER METHOD

The BAT determination by the technology transfer method involves a comparison of BAT effluent treatment systems used on similar effluent streams, to a chosen effluent stream at the Hanford Site (Figure 3). It entails the assembly of data on potentially comparable treatment systems, followed by a determination of comparability. If the selected effluent and Hanford Site streams are comparable, it is likely that similar control technologies may be used at the Hanford Site and established effluent limitations may be adapted. If technology transfer is not feasible, then BAT must be identified by the treatability study method or the generic treatment system method as discussed in Sections 6.0 and 7.0.

5.1 ASSEMBLE INFORMATION ON POTENTIALLY COMPARABLE CASES

Data requirements for the BAT technology transfer method were outlined briefly in Section 3.0. The data should be sufficient to identify similar systems and to reject those treatment systems that are not comparable in influent characteristics and system performance.

The regulatory motivation and effluent limits at other facilities must also be examined to ensure control measures installed were intended to be BAT. At many facilities, controls are designed to meet state regulatory requirements, local water quality concerns, or site-specific environmental objectives, and may go beyond what would be required in a technology-based approach.

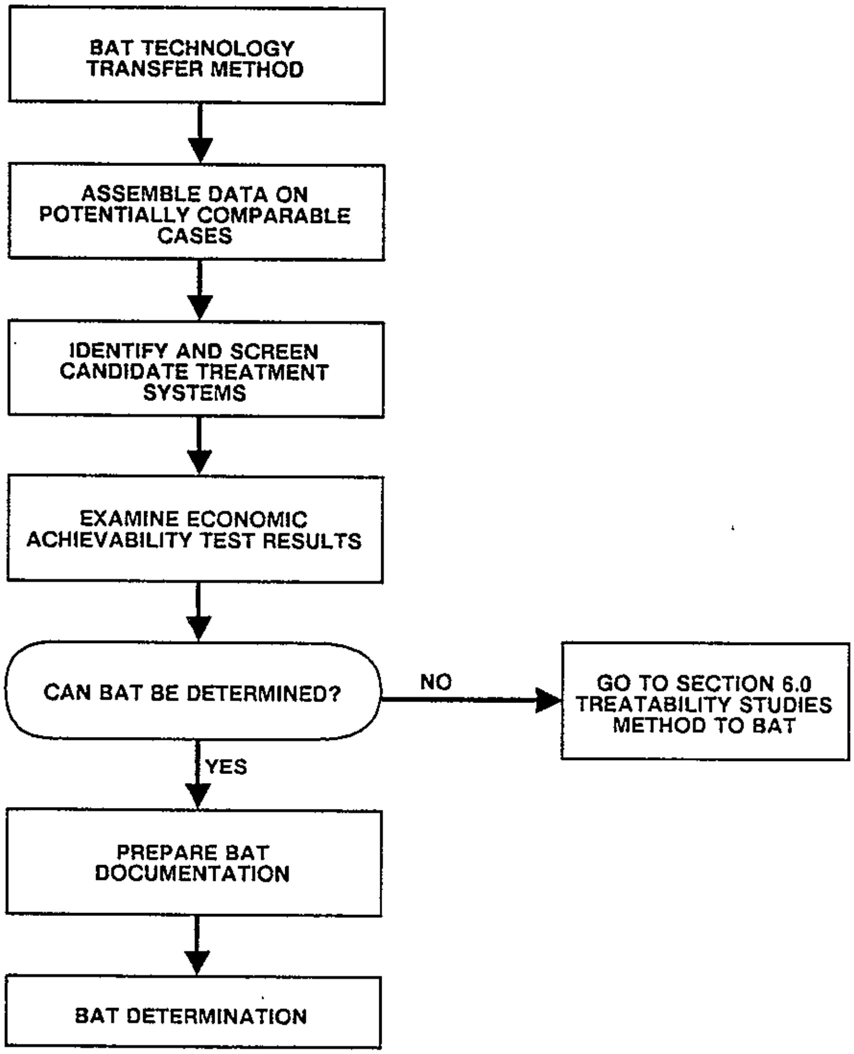
5.2 IDENTIFY AND SCREEN CANDIDATE TREATMENT SYSTEMS

The basic test in applying technology transfer for BAT is to determine how closely the candidate stream compares to the Hanford Site effluent stream in question. Significant differences in pollutants, concentrations, flow, or flow variability may indicate that technology transfer is inappropriate from an engineering standpoint.

In determining whether technology transfer is feasible and in adjusting effluent limitations, the following factors must be considered: Source of effluent, compositional differences, performance data resulting from the treatment of identical pollutants, and system reliability.

5.3 ECONOMIC ACHIEVABILITY TEST

Economic achievability test procedures are delineated in Section 8.0. These tests should be used to assess whether the technically feasible BAT alternatives are economically achievable. Alternatives that fail the economic achievability tests are eliminated from further consideration as BAT, or adjusted as necessary to achieve acceptable effluent quality in a cost-effective manner.



BAT: BEST AVAILABLE TECHNOLOGY.

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Figure 3. Technology Transfer Method to Best Available Technology.

5.4 CAN TECHNOLOGY TRANSFER BE USED TO DETERMINE BEST AVAILABLE TECHNOLOGY?

If no full-scale BAT treatment systems can be found on waste streams comparable to Hanford Site effluent streams, then BAT must be determined by the treatability studies method or the generic treatment system method (see Sections 6.0 and 7.0).

Candidate treatment systems are most likely to be found at facilities that generate waste streams using processes similar to those used at the Hanford Site. A review should be made of treatment systems at DOE facilities nationwide to identify any controlled streams that are sufficiently similar to Hanford Site streams to support the technology transfer method. The conclusions of this review must be reassessed on a regular basis as conditions change.

5.5 PREPARATION OF BEST AVAILABLE TECHNOLOGY DOCUMENTATION

The collection of documentation to support the BAT determination is the final step in the BAT determination process. A report that summarizes the technology-based selection of BAT, which includes sections on liquid effluent characterization, actions to minimize liquid effluent discharges, descriptions of treatment facilities, and applicable technologies should be prepared.

6.0 BEST AVAILABLE TECHNOLOGY DETERMINATION BY TREATABILITY STUDIES METHOD

If effluent guidelines do not exist and technology transfer is not feasible, the treatability studies method can be used to identify BAT. Treatability studies may suggest several control options that could be BAT, based on technical applicability. This method for BAT determination should be used when one treatment technology or treatment system is well established on existing effluent streams similar to the chosen Hanford Site effluent stream, but technology transfer is not feasible. The steps required in the treatability studies method are shown in Figure 4.

6.1 ESTABLISHED OR ATTAINABLE TREATMENT TARGETS AS BEST AVAILABLE TECHNOLOGY

Assembling the information and screening the technologies for the BAT determination process is similar to the technology transfer described in Section 5.0. Through an industry-wide review of control approach practices, it may be possible to identify a level of control that is acceptable as BAT. This will be possible if one of the following two conditions are met:

- A level of treated effluent quality has been accepted for discharge by regulatory agencies
- Current control practices establish a pattern of control efficiency (i.e., percentage removal) or treatment intensity (i.e., number and type of treatment steps).

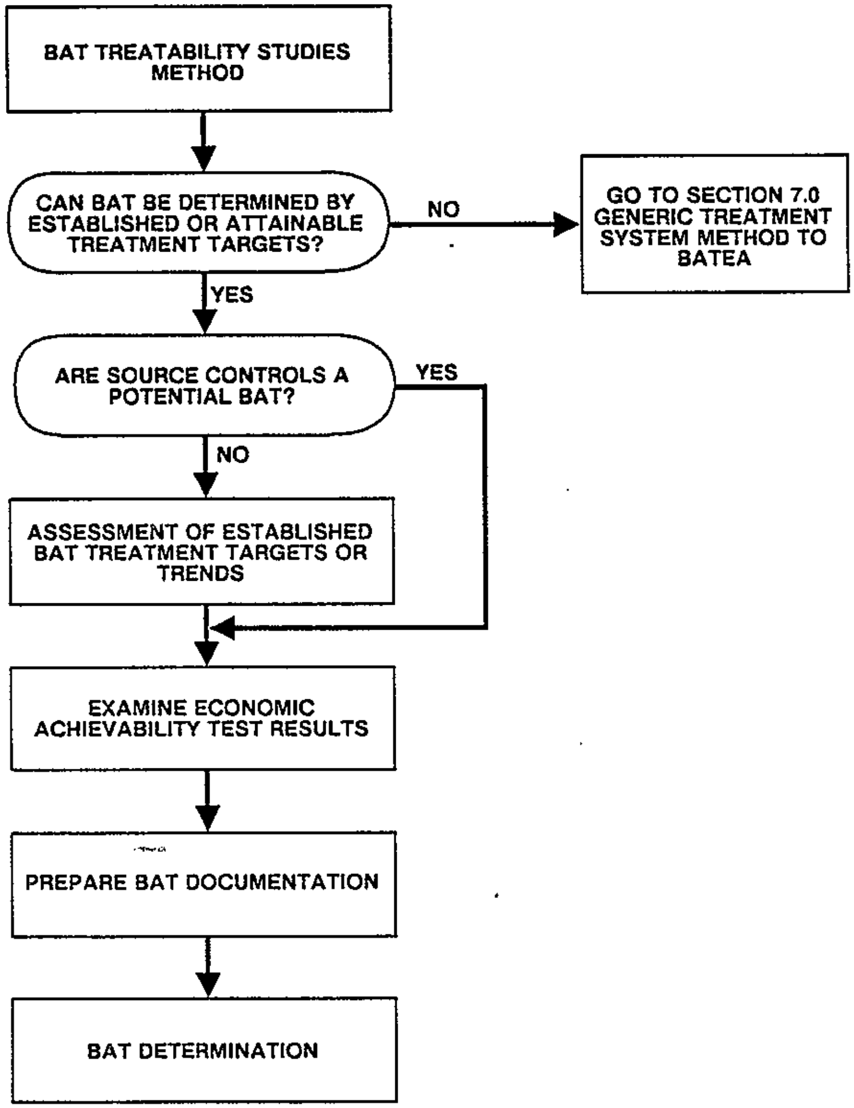
If a pattern cannot be identified, this method is not applicable and the generic treatment systems method should be used to determine BAT (see Section 7.0).

6.2 ARE SOURCE CONTROLS A POTENTIAL BEST AVAILABLE TECHNOLOGY?

Source controls are are a potential BAT for lightly contaminated liquid effluent streams such as steam condensate, cooling waters, and chemical and laboratory sewers.

The evaluations necessary to implement source controls include spill control countermeasure and prevention investigations. These evaluations should be used to identify the source of potential releases of chemical or radiological contaminants in the plant so control and containment may be used to prevent liquid effluent stream contamination.

Source control may also involve water reuse. At the Hanford Site, the radiological content of recirculated fluids will be increased by the buildup of dissolved and suspended radiological materials. This buildup must be controlled by retrofitting barriers, further treatment, or additional discharge of blowdown. The ALARA considerations, with regard to worker exposure within the plant, should also be studied in detail before any of the proposed source control measures with closed-loop water reuse are initiated. Historical closed-loop water reuse experience will have to be modified for both cooling water and steam condensate systems (EPRI 1982; and 1985). Closed-loop water reuse must address the unique combination of equipment, water chemistry, contaminants, blowdown, and control considerations present at the site. Proper selection of treatment programs for these systems requires the collection of substantial amounts of information. This activity is often an extremely difficult task



BATEA: BEST AVAILABLE TECHNOLOGY.

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Figure 4. Treatability Studies Method to Best Available Technology.

due to the complexity of the mechanical equipment involved and the variations encountered in operating conditions. Therefore, source controls will require extensive evaluations to implement successfully.

As indicated in Figure 4, if source controls are potentially BAT, the next step in the treatability studies method is to conduct an economic achievability test.

6.3 ASSESSMENT OF ESTABLISHED BEST AVAILABLE TECHNOLOGY TREATMENT TARGETS OR TRENDS

If source controls cannot be considered as BAT, the next step in the treatability study approach is to determine whether trends or patterns in control efforts have been established. Emerging trends suggest a very aggressive approach to radionuclide control, unless contaminant levels are already below regulatory concerns (i.e., approximately 4 mrem/yr). However, differences in liquid effluent streams, environmental settings, and performance objectives limit the relevance of these cases for BAT determination.

It is almost certain that in the future, treatability studies and control decisions for the Hanford Site and other liquid effluent streams will be sufficient to support this approach to BAT determination. Treatability data would be gathered and compared to the projected liquid effluent stream characteristics and removal efficiencies. The BAT treatment could be identified for this stream on this basis or with additional simple bench-scale tests to confirm the removal efficiencies reported during evaluations of other BAT treatment systems.

6.4 ECONOMIC ACHIEVABILITY TEST

An economic achievability test will be used to assess whether the technically feasible BAT alternatives are economically achievable. The economic achievability test is a reasonable source of guidance to planning BAT needs and is described further in Section 8.0. Alternatives that fail the economic achievability test would be either eliminated from further consideration or adjusted as necessary to achieve acceptable effluent quality in a cost-effective manner.

6.5 PREPARATION OF BEST AVAILABLE TECHNOLOGY DOCUMENTATION

The last step in the determination of BAT by the treatability studies method is to document the BAT determination and to establish release limits, based on actual performance data. These data would be obtained from pilot tests and supporting documentation on technology-based limitations. An engineering report will be prepared to support the BAT treatability studies method.

7.0 THE GENERIC TREATMENT SYSTEM METHOD TO BEST AVAILABLE TECHNOLOGY

The generic treatment system method for determining BAT provides a procedure that can be used to select control alternatives when there is little or no relevant data available on controls for similar effluent streams. The method examines alternative treatment systems where additional control steps are implemented progressively as required by site-specific conditions. The steps involved in the generic treatment system method to BAT are summarized below and shown in Figure 5.

7.1 IDENTIFY APPLICABLE GENERIC TREATMENT SYSTEMS

A generic treatment system can be identified for each effluent stream. The information necessary to identify the applicable generic treatment systems for Hanford Site liquid effluents is included in Figures 6 and 7. These progressive treatment systems will consist of:

- Source controls
- Source controls, pretreatment, and suspended solids removal technology
- Source controls, pretreatment, suspended solids removal, and one step of dissolved solids removal technology
- Source controls, pretreatment, suspended solids removal, and two steps of dissolved solids removal technology.

The source controls generic treatment system can include the following treatment techniques or technologies:

- Waste segregation
- Waste minimization
- Closed-loop systems
- Recirculation systems
- Spill control
- Spill containment
- Procedure modifications.

The BAT treatment system that provides the next level of treatment may include the following treatment techniques or technologies:

- Source controls, as described previously without closed-loop water reuse
- Pretreatment with flow equalization

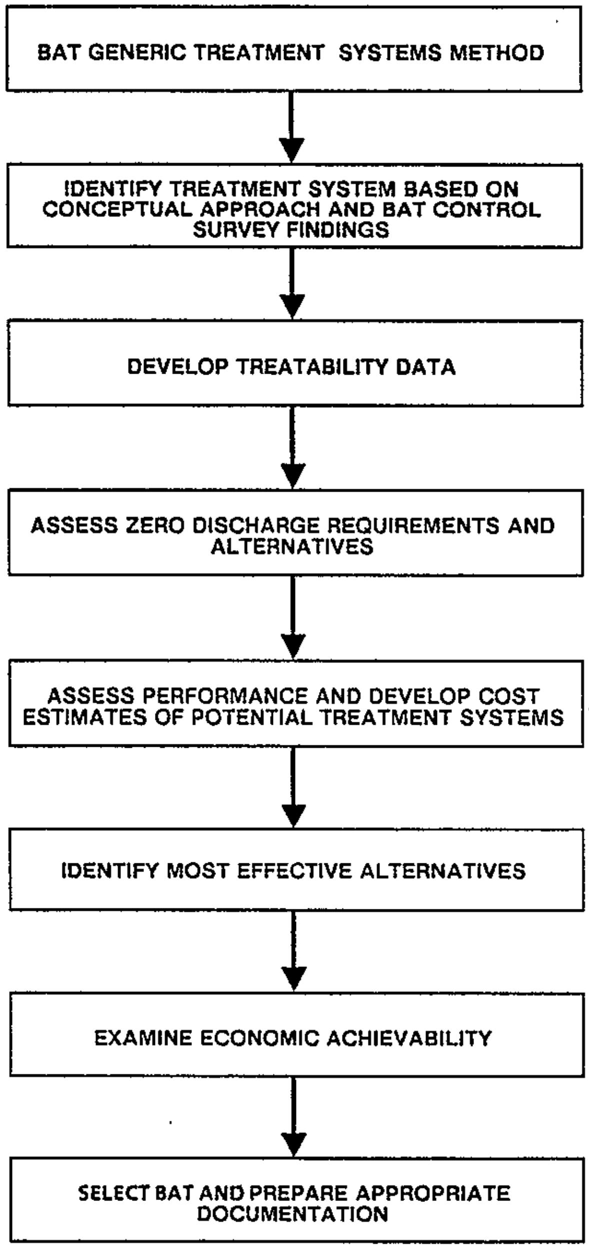

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Figure 5. Generic Treatment Systems Method to Best Available Technology.

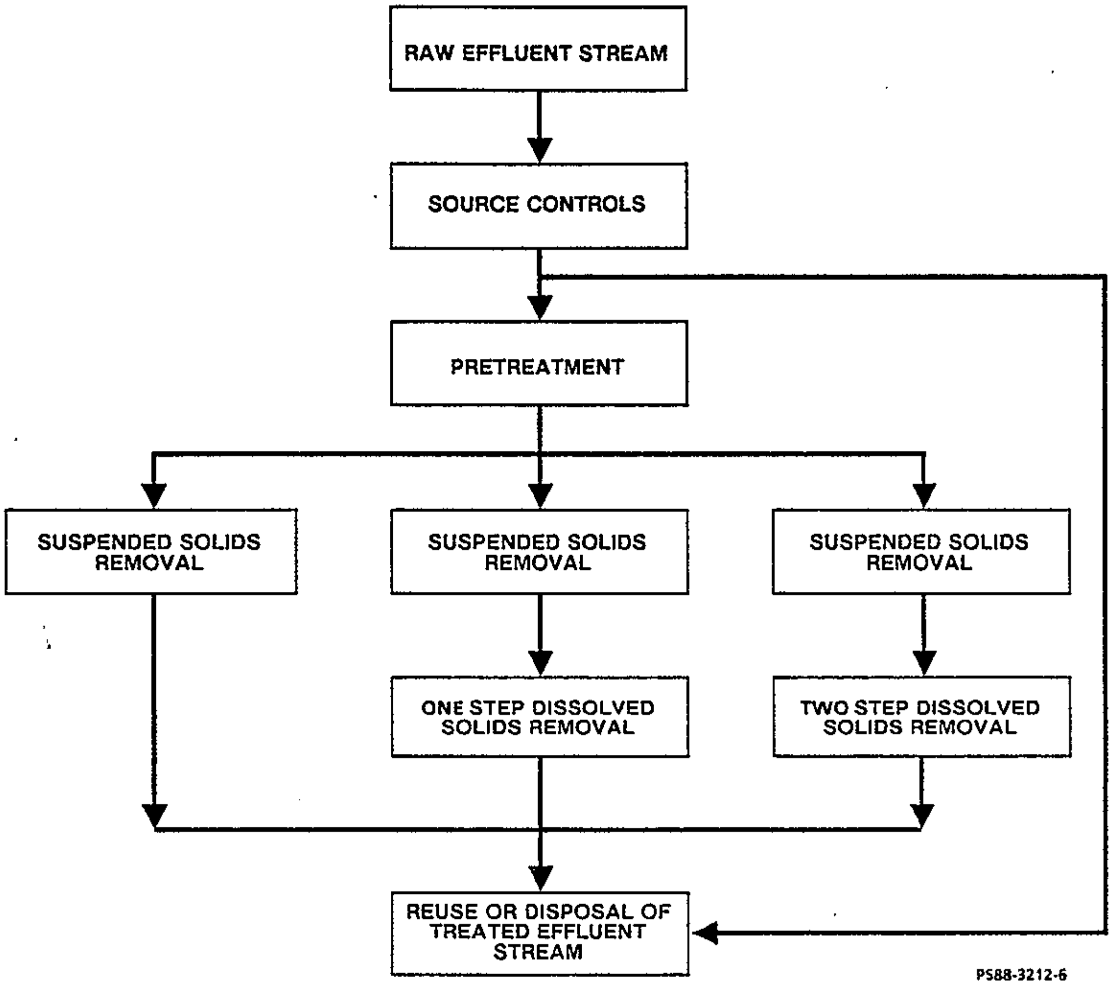

Figure 6. Potential Control/Treatment Systems Diagram for Hanford Site Liquid Effluent Streams.

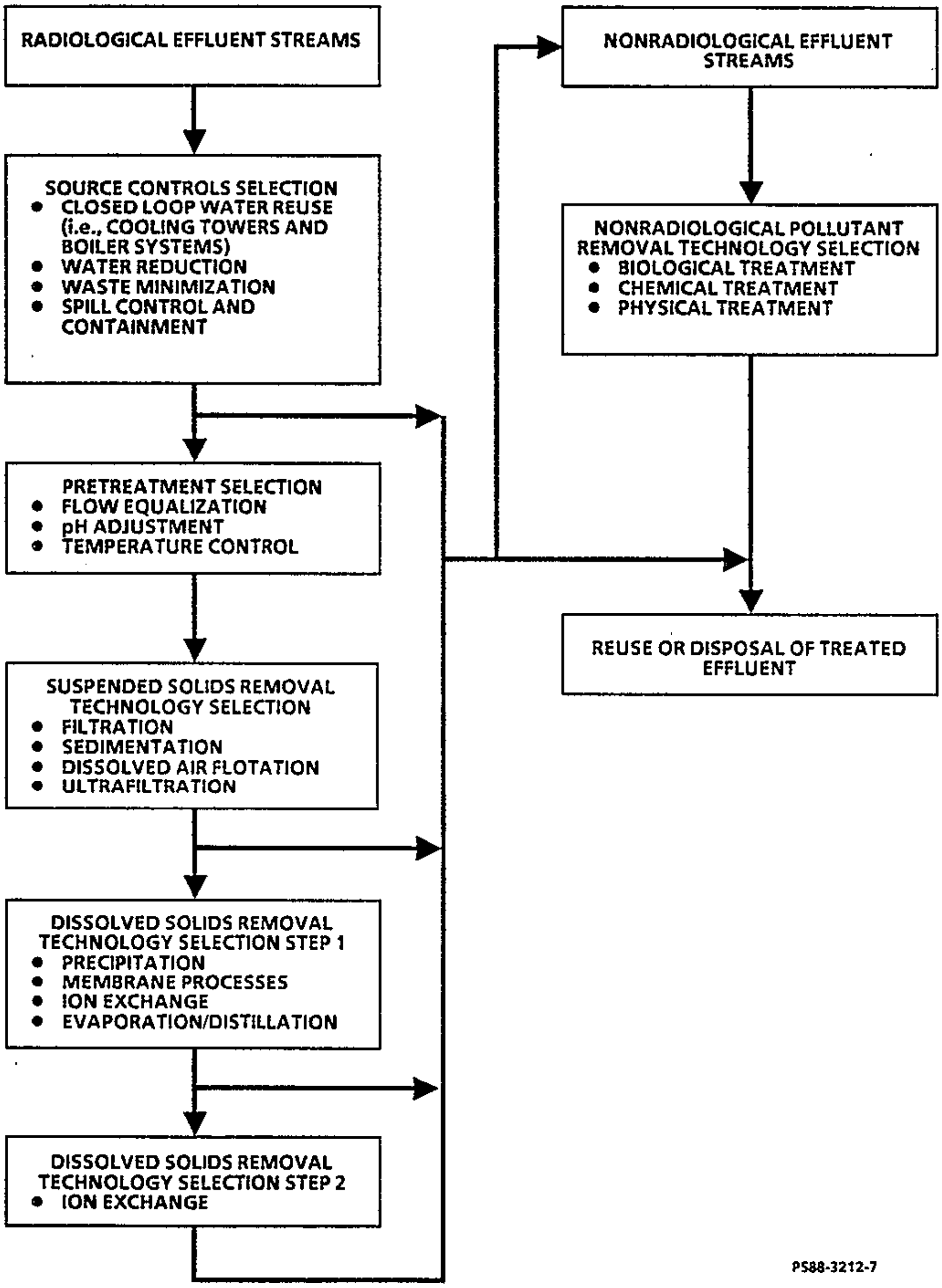

Figure 7. Development of Radiological Pollutant Treatment Systems from Applicable Best Available Technology.

- pH adjustment, chemical additions, or temperature control
- Suspended solids removal technologies such as filtration or sedimentation.

The third, more progressive, alternative treatment system may include the following treatment techniques or technologies:

- Source controls
- Suspended solids removal
- One step of dissolved solids removal, potentially including precipitation, ion exchange, membrane processes, or evaporation/distillation.

The fourth alternative treatment system may include all of the treatment steps of the third alternative, plus another dissolved solids removal step (potentially ion exchange).

The next step in the generic treatment system method is to develop the treatability data so the performance and cost-effectiveness of the selected generic system may be assessed.

7.2 DEVELOP TREATABILITY DATA FOR THE SELECTED GENERIC TREATMENT SYSTEM

The generic treatment systems identified in Section 7.1 provide a potential set of solutions for treatment of liquid effluent streams at the Hanford Site. The basic approach to developing these solutions uses a conventional treatability analysis. This analysis follows the eight basic steps (Perry 1984) summarized as follows:

7.2.1 Define the Overall Effluent Treatment Problem

Defining the overall treatment problem requires a complete understanding of the effluent generation process and the preceding and subsequent steps in the treatment process.

7.2.2 Establish Process Conditions

Establishing process conditions means defining the effluent treatment problem in detail:

- Properties of the materials to be separated, the quantities of feed and discharge required, the range of operating variables, and any restrictions on materials of construction must be accurately fixed, or reasonable assumptions must be made
- Accurate data on particle size, size distribution, partitioning of pollutant species, densities, viscosity, and other physical properties should be obtained
- Qualitative considerations such as secondary waste generation rates, energy usage, and ALARA considerations may also influence effluent treatment systems selection.

7.2.3 Make Preliminary Selections of Treatment Alternatives

Preliminary selections of promising effluent treatment technologies should be made in the manner outlined in Section 7.1.

7.2.4 Take Representative Samples

Representative samples are taken randomly and under widely varying conditions to obtain meaningful treatability study results. Samples should be taken from all operating shifts in continuous processes or from successive batches for batch processes that generate liquid effluents. The influences of variations in treatment characteristics such as influent flow, temperature, and concentration should be investigated. Having taken a sample for bench- and/or pilot-scale tests, they must be handled and preserved properly to ensure accurate test results.

7.2.5 Make Simple Preliminary Tests

Tests of treatment technologies at the bench-scale level should recognize the results may require confirmation through pilot-scale testing. Bench-scale tests like the Silt Index Test (i.e., a test for the build-up of fine solids), jar tests, filtration, and other small-scale functional tests provide useful data to evaluate the various treatment technologies and systems. In some cases, decontamination factors (i.e., a representation of pollutant removal efficiencies) from previous pilot plant studies on similar liquid effluents may be used to evaluate treatment systems.

7.2.6 Modify Process Conditions

The modification of process conditions may change an otherwise infeasible treatment approach into a viable BAT candidate. One example is partial closed-loop water reuse. Another example would be the use of flocculating agents, and/or temperature and pH control.

7.2.7 Consult Equipment Manufacturers

Equipment manufacturers can provide useful first-hand knowledge of full-scale operations, test center facilities, and pilot test equipment.

7.2.8 Make Final Selection

The selection of candidate BAT treatment systems will be made in the context of engineering and regulatory criteria. This selection will be based on treatment system performance and cost effectiveness, acceptable treated effluent quality, decisions on the ability of the treatment systems to achieve treatment goals, assessment of zero discharge, and a test of economic achievability.

7.3 ASSESS ZERO DISCHARGE REQUIREMENTS AND ALTERNATIVES

The BAT determinations sometimes specify that some pollutants not be discharged. This is most likely where pollutants are persistent and harmful in any quantity, and where it is possible to keep the contaminant out of the discharge stream (e.g., through source controls). The BAT limits for polychlorinated biphenols (PCB), for example, may specify zero discharge. A zero discharge may also be specified where substantial removal of a pollutant before discharge is not possible; in this case, control requires that discharge be avoided (e.g., through impoundment, further treatment, evaporation, recycle, or other techniques).

For control measures to be BAT, they must address all significant pollutants of concern in a liquid effluent stream. If end-of-pipe control is infeasible, consideration should be given to the feasibility and appropriateness of zero discharge alternatives and aggressive source control practices unless control is technically infeasible. Closed-loop systems represent a zero discharge source control alternative. Partially closed-loop systems might allow a reduction in effluent discharge for cooling waters and steam condensate. In addition, water reduction, waste minimization, and spill control and containment merit further consideration for most streams.

7.4 ASSESS PERFORMANCE AND DEVELOP COST ESTIMATES FOR THE POTENTIAL TREATMENT SYSTEMS

An assessment of generic treatment system performance and cost is important in reducing the number of potential treatment systems to one or two generic treatment system alternatives. This is done by developing rough order-of-magnitude costs with standard estimating techniques, adjusted for Hanford Site conditions.

When the reduced list of applicable generic treatment system alternatives is selected, conceptual design cost estimates will be required to successfully distinguish differences between treatment systems that provide comparable pollutant removal efficiencies.

7.5 IDENTIFY MOST EFFECTIVE ALTERNATIVES

A decision analysis technique like Kepner and Tregoe (1981) may be used to select the treatment alternative that can produce a potentially acceptable treated effluent quality. A problem statement or decision statement must be prepared so all relevant factors that may affect treatment system performance can be assessed. The objective for the decision analysis is developed from the following examples:

- Must Criteria
  - Acceptable treated effluent quality
  - Operator and public safety
  - Project deadlines
- Want Criteria
  - Least cost
  - Reliability (i.e., proven technology at a number of facilities)
  - Flexible operation (i.e., responds well to flow and concentration variation)
  - Ease of maintenance

- Impact on operations during construction (i.e., construction should not interfere with the facility mission)

- Ease of technology development (i.e., bench-, pilot-, or full-scale)

- Minimize secondary waste generation

- Improve operating efficiency.

Weighing factors and scores are assigned to each "want" criteria to identify the most effective alternative.

7.6 ECONOMIC ACHIEVABILITY TEST

The economic achievability test will be used to assess whether the technically feasible BAT alternatives are economic. The tests will aid in the determination of BAT, as well as prioritize treatment system projects. Additional explanation is presented in Section 8.0. Alternatives that fail the economic achievability tests would be either eliminated from further consideration as BAT or adjusted as necessary to achieve acceptable effluent quality in a cost-effective manner.

7.7 PREPARATION OF BEST AVAILABLE TECHNOLOGY DOCUMENTATION

The final step in the determination of BAT by the generic treatment systems method involves preparing appropriate documentation. A report that summarizes BAT selection should be prepared. This report could then be used to establish and summarize release limits for the treatment system.

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8.0 ECONOMIC ACHIEVABILITY ANALYSIS

This section describes the steps necessary to apply a "cost ratio method" and a "cost-effectiveness method" for determining economic achievability. The cost ratio method is patterned on tests the EPA applies to commercial enterprises and compares plant operating costs to pollution control costs. The cost-effectiveness method is based on the more fundamental idea that costs of controls should be related reasonably to the benefits of controls.

8.1 THE COST RATIO METHOD

The proposed cost ratio method is a surrogate for a revenue ratio test described in EPA guidance (EPA 1983a; and 1983b). A revenue ratio test cannot be applied directly at the Hanford Site because Hanford Site facilities do not have actual revenues.

The cost ratio method is based on the ratio between control costs and total production costs, with a threshold level of achievability for this ratio developed by reference to data on similar commercial enterprises. The method uses data that are likely to be available and data interpretation methods that are consistent with EPA practice. It is intuitively appealing, because it is based on the proposition that the ratio of control costs to production costs that is reasonable at a Federal facility should be related to the ratio of such costs that is economically achievable at similar private sector facilities.

The application of this method requires calculating the annualized cost of the liquid effluent treatment system and the annualized total cost of the waste generating facility. Annualized values are the sum of the net present value of the facility and the facility operating expenses, averaged over the remaining life of the facility. In the simple case of an initial capital investment and annual operating and maintenance (O&M) costs, the annualized costs are equivalent to the annual payment that would be needed to service and retire a loan (of the capital cost) over the life of the facility plus annual O&M costs. Care must be taken in calculating annualized values to ensure they are representative of future conditions.

Estimates of facility life spans and the selection of discount or interest rates must be considered because these values are important in making the necessary annuity adjustments for calculating equivalent cost values. A discount rate based on long-term treasury bill interest rates is appropriate for a Federal facility. In calculating annualized costs for the waste-generating facility, capital investments that have already been irrevocably committed should not be considered. Necessary capital improvements should also be considered.

As an initial reference, if the ratio of annualized control costs to annualized facility cost is less than 5%, controls are economically achievable. If this ratio is greater than 5%, additional analysis of financial data is necessary to determine an appropriate threshold of economic achievability for similar kinds of activity. As more experience is gained in this method, a more appropriate threshold level of economic achievability may be established.

8.2 THE COST-EFFECTIVENESS METHOD

The EPA assesses cost effectiveness of many effluent guidelines by comparing the incremental removal of toxic pollutants to the incremental cost of controls. To allow comparisons of various pollutants, the EPA has developed equivalency factors. These equivalency factors are based on the toxic potential of the pollutants if discharged to an aquatic environment. These calculations are performed to meet EPA obligations under Executive Order 12291 to calculate the costs and benefits of regulations.

Weights for toxic contaminants begin with human health and water quality criteria as developed by the EPA. Human health criteria are based on the ingestion of 6.5 g/d of fish taken from water contaminated by the effluent. Chronic ambient water quality criteria are based on the 4-d maximum allowable concentration. Values of these criteria have been published (EPA 1980; and 50 FR 30784). Ambient water quality criteria are also published in 50 FR 30784. Most pollutants have a reference criteria for at least one of the two, and often for both the human and the water quality criteria.

A specified reference value based on the criteria for copper is divided by the specific water quality criteria values. If both human health and water quality criteria are present, these quotients are added. The resulting value is the estimated "toxic weight," which corresponds to the estimated relative toxicity of the component. Cost-effectiveness is then calculated by dividing the incremental cost of liquid effluent treatment control options by the incremental pound equivalent of pollutants removed.

The EPA has not developed toxic weights for radionuclides. However, toxic weights developed for radionuclides may be calculated, based on Washington State definition of deleterious concentrations of radionuclides in surface waters (WAC 173-201-035(11)) and an assumption that those limits are equivalent to EPA aquatic toxicity standards (EPA 1980).

The basic approach to calculating toxicity weight cost-effectiveness includes the following steps:

- Array treatment options in order of increasing cost
- Calculate the <u>incremental</u> removal of each toxic pollutant or radionuclide with an established chronic ambient water criterion
- Multiply the incremental removals by their respective toxic weights to get pound equivalent removed
  - The toxic weight of each contaminant is defined as the water quality criteria for copper divided by the specific water quality criteria
  - The result is defined as pound equivalents removed
- Add each pound equivalent removed to obtain the sum of the pound equivalents
- Divide the sum of the pound equivalents removed by the respective incremental costs of the treatment system.

As an initial reference, an incremental cost between $40 and $90 per pound equivalent removed, seems to be an appropriate threshold for determining the cost-effectiveness of a treatment system. As more experience is gained in this test, a more realistic threshold may be established.

9.0 REFERENCES

AEA, 1954, *Atomic Energy Act of 1954* (as ammended), 42 U.S.C. 2011 et seq., U.S. Congress, Washington, D.C.

AWWA, 1980, *Standard Methods for Examination of Water and Wastewater*, Fifteenth Edition, American Water Works Association, American Public Health Association, Washington, D.C.

DOE, 1984, *Radioactive Waste Management*, DOE Order 5820.2, U.S. Department of Energy, Washington, D.C.

DOE, 1987, *Final Environmental Impact Statement: Disposal of Hanford Defense High-Level, Transuranic, and Tank Wastes*, DOE/EIS 013, U.S. Department of Energy, Washington, D.C.

DOE-RL, 1987, *Plan and Schedule to Discontinue Disposal of Contaminated Liquids into the Soil Column at the Hanford Site*, Response to Congressional Request, March 16, 1987, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

Ecology, 1973, *Water Quality Standards for Waters of the State of Washington*, WAC 173-201, Washington State Department of Ecology, Olympia, Washington.

Ecology, 1974, *National Pollution Discharge Elimination System Permit Program*, WAC 173-220, Washington State Department of Ecology, Olympia, Washington.

Ecology, 1983a, *State Waste Discharge Permit Program*, WAC 173-216, Washington State Department of Ecology, Olympia, Washington.

Ecology, 1983b, *Underground Injection Control Program*, WAC 173-218, Washington State Department of Ecology, Olympia, Washington.

Ecology, 1983c, *Washington Water Pollution Control Act*, RCW 90.48, Washington State Department of Ecology, Olympia, Washington.

EPA, 1973, "Physical-Chemical Wastewater Treatment Plant Design," *EPA Technology Transfer Seminar Publication*, U.S. Environmental Protection Agency, August 1973, Washington, D.C.

EPA, 1974a, "Wastewater Filtration-Design Considerations," *EPA Technology Transfer Seminar Publication*, U.S. Environmental Protection Agency, July 1974, Washington, D.C.

EPA, 1974b, "Flow Equalization," *EPA Technology Transfer Seminar Publication*, U.S. Environmental Protection Agency, May 1974, Washington, D.C.

EPA, 1980, *Ambient Water Quality Criteria and Standards*, EPA-440/5-80, U.S. Environmental Protection Agency, Office of Water Regulations and Standards, Criteria for Standards Division, Washington, D.C.

EPA, 1981a, *Treatability Manual, Volume II - Industrial Descriptions*, EPA-600/2-82/001b, U.S. Environmental Protection Agency, Office of Research and Development, Washington, D.C.

EPA, 1981b, *Treatability Manual, Volume III - Technologies for Control/Removal of Pollutants*, EPA-600/2-82-001c, U.S. Environmental Protection Agency, Office of Research and Development, Washington, D.C.

EPA, 1983a, *Guidance Manual for Estimating the Economic Effects of Pollution Control*, U.S. Environmental Protection Agency, Office of Analysis and Evaluation, Washington, D.C.

EPA, 1983b, *Workbook for Estimating the Economic Effects of Pollution Control*, U.S. Environmental Protection Agency, Office of Analysis and Evaluation, Washington, D.C.

EPA, 1986, *Development of Case by Case Discharge Permits Under the National Pollutant Discharge Elimination System and Pretreatment Programs* (Draft), U.S. Environmental Protection Agency, Region VIII, Denver, Colorado.

EPA, 1988a, "Energy," *Title 10, Code of Federal Regulations*, U.S. Environmental Protection Agency, Washington, D.C.

EPA, 1988b, "Protection of Environment," *Title 40, Code of Federal Regulations*, U.S. Environmental Protection Agency, Washington, D.C.

EPRI, 1982, *Design and Operating Guidelines Manual for Cooling-Water Treatment - Treatment of Recirculating Cooling Water*, prepared by Stearns Roger Engineering Corporation for the Electric Power Research Institute, Palo Alto, California.

EPRI, 1985, *Design and Operation Checklists for Zero Discharge Power Plant Water Systems*, CS-4045, prepared by Water Management Associates for the Electric Power Research Institute, Palo Alto, California.

Kepner, C. H., and B. B. Tregoe, 1981, *The New Rational Manager*, Princeton Research Press, Princeton, New Jersey.

NALCO, 1988, *The NALCO Water Handbook*, Second Edition, McGraw-Hill Company, New York, New York.

Perry, ed., 1984, *Perry's Chemical Engineer's Handbook*, Sixth Edition, McGraw Hill, Inc., New York, New York.

APPENDIX A

ACRONYM LIST

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APPENDIX A

ACRONYM LIST

AEA	Atomic Energy Act
ALARA	as low as reasonably achievable
ARAR	Applicable or Relevant and Appropriate Requirements
BAT	Best Available Technology (economically achievable)
BPJ	Best Professional Judgement
CERCLA	Comprehensive Environmental Response Compensation and Liability Act
CWA	Clean Water Act
DOE	U.S. Department of Energy
DOE-RL	U.S. Department of Energy-Richland Operations Office
EPA	U.S. Environmental Protection Agency
FCZ	future control zone
MCL	Maximum Concentration Limit
NPDES	National Pollution Discharge Elimination System
NRC	U.S. Nuclear Regulatory Commission
O&M	Operating and Maintenance
PCB	Polychlorinated biphenols
RCRA	Resource Conservation and Recovery Act
WAC	Washington State Administrative Code
Westinghouse Hanford	Westinghouse Hanford Company
WWPCA	Washington Water Pollution Control Act

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